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PROCEEDINGS OF THE CONFERENCE

ON

**HIGHWAY ECONOMICS AND
HIGHWAY TRANSPORT**

HELD AT THE

UNIVERSITY OF TENNESSEE
KNOXVILLE

OCTOBER 10-11, 1921

Edited by

N. W. DOUGHERTY



Published by the

HIGHWAY EDUCATION BOARD

Formerly the Highway and Highway Transport
Education Committee

Willard Building, Washington, D. C.

1922

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Willard Building, Washington, D. C.

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Conference on highway engineering and
highway transport education (Regional)
University of Tennessee, Oct. 10-11, 1921

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Program

Regional Conference for Study of Highway Economics and Highway Transport, The University of Tennessee, Knoxville. Cooperating with Highway Education Board, October 10, 11, 1921.

Monday, October 10

BUSINESS MEN'S CLUB

- 2.00 p. m. H. A. Morgan, President, the University of Tennessee, Remarks on Rural Transportation.
- 2.30 p. m. Thomas H. MacDonald, Chief, Bureau of Public Roads, U. S. Department of Agriculture, The Problems to be Studied.
- 3.00 p. m. N. W. Dougherty, Professor Civil Engineering, University of Tennessee, Highway Economics and Highway Transport in Typical Counties of Tennessee. Discussion.
- 6.30 p. m. Dinner, Business Men's Club.
Visiting delegates guests of Knoxville Board of Commerce and Knoxville Automobile Club.

Address M. O. Eldridge, Washington, D. C., Director of Roads, American Automobile Association, Highway Hazards.

Address, Major I. C. Moller, 25 Broadway, New York City.
Cost of Motor Vehicle Operation.

Address, Pyke Johnson, Chairman, Highways Committee, National Automobile Chamber of Commerce, Washington, D. C.,
The Living Road.

Tuesday, October 11

ESTABROOK HALL, UNIVERSITY OF TENNESSEE

- 9.00 a. m. B. L. Cunliff, Maintenance Engineer, Tennessee Department of Highways, Report of Maintenance Plan for Tennessee.
Discussion.
- 10.00 a. m. General discussion.
- 11.00 a. m. H. G. McGee, Bureau of Municipal Research, Akron, Ohio.
Justifiable Expenditure on the Highway Program.
Discussion.
- 12.30 m. Luncheon.
Visiting delegates guests of Engineering College.
- 2.00 p. m. Automobile trip inspecting highways and highway construction.

Introductory

The Sixth Regional Conference held under the auspices of the Highway Education Board, formerly the Highway and Highway Transport Education Committee, was called to order by Dean Charles E. Ferris of the College of Engineering, University of Tennessee. Dean Ferris welcomed the delegates to Knoxville and to the University. He stated briefly the events which led up to the conference and expressed the hope that out of the conference lasting good would come to Tennessee and the adjoining states. Delegates were asked to register and states were represented as follows: Alabama, Arkansas, Georgia, New York, District of Columbia and Tennessee.

D. Q. McComb, Chief Engineer of the Tennessee Department of Highways, was elected permanent chairman of the conference. Walter S. Smith was elected secretary.

The conference met in three regular sessions; namely, the afternoon and evening of October 10, and morning of October 11. The proceedings of this conference are confined to the papers presented at these sessions. In addition to the regular sessions the delegates engaged in round table discussions at the luncheon held at noon, October 11. Practically all delegates present entered into the discussion. Stenographic records were not taken and as a consequence the discussion of the round table cannot be printed in these proceedings.

N. W. DOUGHERTY.

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Remarks of Dr. H. A. Morgan

President of the University of Tennessee

Rural transportation is one of the big questions that is before the people today. It means much to the city dweller to travel in comfort over miles of country roads, but the smooth, hard surfaced highway means more than comfort and relaxation to the farmer. The country church—the heart of the community—the consolidated school, which has grown to rival the best city school, increased rural mail service, the social life so vital to make a contented people—all demand improved roads. Good roads expand the zone for profitable growing of perishable crops and for the production of dairy products; they better marketing conditions; they reduce the cost of marketing; they encourage production.

Unfortunately, economic study of highway transportation has been neglected. Much wealth has been wasted through our ignorance of the exact problem to be solved, and of the correct solution. We have built roads unfitted to the traffic which they must carry. It is my pleasure, therefore, as president of the University of Tennessee, to welcome you to this conference for the study of highway economics. We sincerely hope that out of this conference will come much valuable information that will guide us in the wise expenditure of the funds which our people have generously voted for the building of better roads. With 75 per cent of the population of the state living in rural communities, or on farms, it is but logical that the University of Tennessee should be interested in the problems of rural transportation.

Years ago the College of Engineering began holding annual conferences of county officials responsible for the building and maintenance of highways. This beginning has grown into a winter short course of six weeks, conducted by the Engineering Faculty, cooperating with the Engineers of the State Highway Department.

When the first State Highway Commission was formed, the Dean of the College of Engineering was an ex-officio member and for four years gave much time and thought to the organization of this work. The Engineering College under his leadership devotes much time to instruction in Highway Engineering. Regular courses in the study of Highway Construction and Highway Economics are offered to students of the University. Similar courses are offered to the students of the six weeks short course.

As a result of this activity on the part of the University in the solution of the transportation problems, it is interesting to note that fully 50 per cent of the engineers now engaged in the building of highways in the state received their technical training either in our annual short courses or at the four-year courses offered by the College of Engineering.

The Problems To Be Studied

BY THOMAS H. MACDONALD

Chief of the U. S. Bureau of Public Roads

There is a term frequently used at such meetings as this that I should like to see stricken out of our vocabularies and erased from every program. I refer to the hackneyed term "good roads." It has been used so long and so questionably in connection with an outgrown propaganda that it no longer stands for our ideas of the goal toward which we are now working. What we are interested in now is not "good roads" or "better roads" but better transportation, which involves not roads only but vehicles as well, and the proper relation of the vehicle to the road.

We are meeting here in conference under the auspices of the University of Tennessee in order that we may discuss some of the problems that lie before us in preparing the way for better transportation; and that we may decide upon methods and means by which young men who are now studying in the engineering courses of the universities may be brought up in the knowledge of these problems.

The University is cooperating in this movement with the Highway Education Board. The Board, formerly known as the Highway and Highway Transport Education Committee, and gathered together as the result of a conference held in Washington over a year ago, is made up of representatives of government departments and private industry. On it are represented the War Department, the Agricultural Department through the Bureau of Public Roads, the Bureau of Education, the Society for the Promotion of Engineering Education, the Rubber Association of America and the National Automobile Chamber of Commerce. As you will see, it combines in its membership the producers of vehicles, the builders and the users of roads, and the educators upon whom must fall the task of training those who are to work for the development of the new idea of highway transport which differs from the old "good roads" propaganda as day from night.

ROADS WITHOUT RHYME OR REASON

To the "good roads" enthusiast the good road was the end to be sought—a thing to be possessed for itself alone—something in which the community could properly take pride, as in a new monument for the courthouse square. His demand was for the best road obtainable, usually with total disregard for the character or volume of the traffic to be accommodated. Largely at his behest we have begun upon the development of our highways without system and without method. Without rhyme or reason we have built a piece of good road here, another there, each as they were demanded by this or that community acting upon the urge of its "good roads" enthusiasts.

These roads have been built for the locality rather than for the state or nation. In general they are not connected with each other, and, in some

instances, their location is so lacking in elements of economy as to warrant no connection with the highway systems which are now being developed.

With such a conception of the purpose of roads our present ideas of highway transportation have no relation. Within our broader view there lies a national system of connected roads, each road a link in the national chain, bearing its due proportion of interstate traffic, yet each a local road as well, serving with well-placed lateral roads to distribute and collect the traffic of the rural sections. Each road in our projected system must be designed for the particular traffic it will be called upon to carry. There must be no superfluous expenditure for roads beyond the economic requirements of the vehicles that will use them, yet the roads built must be fully adequate if we would avoid waste and deterioration.

FOUR LINES OF ATTACK

It has been given to me to outline—not to solve—the problems we confront in building such a system and providing for highway transportation in this higher sense. To outline them is not a difficult matter; to solve them is a task for many men and long, unselfish labor. Only now, I feel, are we approaching the study of these problems in the proper manner.

The lines along which we are attacking them are as follows: (1) Highway Economics; (2) Highway Engineering; (3) Automotive Engineering; (4) Highway Transport.

I place first the line of highway economics because it is along that line that we propose to find out why and for what purpose we should build the roads; in a general way, where they should be; and how we may best pay for them. It is in this first line of attack that Prof. N. W. Dougherty, of the University of Tennessee, is working. We have made arrangements with him to study the use of the roads in Tennessee; to show the use you are now making of your highways, the probable effect of improved roads on the distribution of traffic, and the value of such improved roads as a means of bettering transportation conditions in the state. I am hopeful that he will be able to continue his studies until he has covered all the counties of the state, for I know of no way in which he can render better or more important service to the state. He has had splendid cooperation from every one, and in a little while, if his work is continued, he should be able to say to the state: "This is the service our highways are giving us now, and these are the developments of service that improved highways can bring to us."

Along the second line—that of highway engineering—we are studying the design of roads from the technical standpoint and endeavoring to develop better methods of construction, and especially of maintenance. In order to improve our designs we are going into a study of subsoils and foundations and wearing surfaces, the effect of climate, drainage and loading; and we are finding some things that will, I believe, surprise most people. It is the popular belief, I am sure, that our highway surfaces are absolutely inert and stationary and that they remain in one place and one position until they are worn out. That is not correct, we find. For example, take a concrete road; it is

constantly moving; back and forth lengthwise, as seasons change, and expansion gives way to contraction, and vice versa; and up and down each day. During the day the edges of the slabs curl down as the upper surface expands under the influence of mounting temperature; at night they curl up when the surface cools and contracts. We have measured displacements of the slab as great as half an inch from the subgrade. Should a heavily loaded truck come along at such times it would find the road in the air with absolutely no subgrade support, and it is easy to imagine what would happen.

KNOWLEDGE IMPERATIVE BEFORE INVESTMENT

In our studies to determine how thick we shall make our road surfaces and their foundations we are investigating the effect of the impact of motor trucks. Due to irregularities in the surface of the roads, it is not unusual for a heavily loaded truck to fall with a thud upon the road surface from a height of a quarter or even half an inch. At such times the blow delivered to the road is equivalent to many times the weight of the truck and load. We have measured blows equivalent to 20 tons and more, yet people wonder why our roads break down.

We must discover such facts as these before we invest our money, because it is impossible to build roads that will hold up properly unless we find out exactly what conditions we must build them for—just as a tailor must measure you before he can cut the cloth.

Along the line of automotive engineering are those problems of size and distribution of the load, economic truck capacity, design of the various parts of the truck for economy in operation, etc. As related to the roads there is the study of the value and effect of various kinds of tires in relieving and cushioning the blows of impact, and the possibility of better distribution of the weight of the load to the road. I am trying to convince my automobile friends that we have found trucks so designed that we get the equivalent of 110 per cent of the carried load under the two rear wheels alone. Such a concentration of load is, of course, extremely difficult to cope with, and one phase of our study aims to relieve this condition by a more uniform distribution to four or six wheels.

Along the fourth line, that of highway transport, lie the broad problems involved in the development of an economic system of roads and the use and regulation of such a system to supplement the other transportation systems and relieve the dangerous situation into which we have been permitted to drift by failure of our transport to keep pace with our production.

I do not know of any state in the Union that will be helped more by the development of a system of primary and feeder roads than the State of Tennessee. If you will tie this whole state together, from the east to the west, and from the north to the south, with primary roads, joined to feeder roads, there will come about a development of your state that cannot be brought about in any other way.

Highway Economics and Highway Transport in Typical Counties of Tennessee

N. W. DOUGHERTY, *Professor of Civil Engineering,*
University of Tennessee

In anticipation of the conference, the Bureau of Public Roads, the University of Tennessee, the Tennessee Highway Department and a number of Tennessee counties undertook a survey during the summer months. Before undertaking to accumulate field data a general outline of highway economics and highway transport was developed. From the very beginning of the survey it was apparent that information could not be obtained on all phases of the outline. Some of the divisions—the materials survey, for example—will require much time and effort before complete results may be obtained.

Enough work, however, was accomplished to demonstrate the feasibility of the method and to point the way to a more complete survey in the future. I shall undertake to give you an outline of the work and some of the results already obtained.

OUTLINE

I. Highway Evaluation—Existing System.

1. Type and Condition of Surface.
 - a. Kind of surface—macadam, gravel, concrete, etc.
 - b. Classification of type according to condition.
 - c. Cost of road—time constructed, etc.
2. Kind of Soil.
 - a. Classification of soils for subgrade.
 - b. Soils for cuts and embankments.
3. Major Topographic Features.
 - a. Grades and alignment relation to construction costs and probable future operation.
 - b. Drainage conditions. Is drainage adequate?
 - c. Bridges—type, strength, when built.
 - d. Width of traveled way.
 - e. Climatic conditions.

II. Maintenance.

1. Systems Used.
2. Costs of Several Selected Roads.
3. Method of Financing.
4. Degree of Success Considering System and Traffic.

III. Service Road is Giving or May Give.

1. Traffic Counts.
 - a. Plan and period of census.
Selection of census points.
Accumulate previous data for points taken.

- Classification of vehicles.
- Actual count.
- b. Study of traffic data.
 - Character of traffic.
 - Local, farm-to-market, pleasure, city-to-farm.
 - Through, as interurban or inter-state.
 - Truck, interurban, farm-to-market, market-to-farm.
 - Length of haul.
 - Tonnage of each class of traffic.
 - Value of produce hauled.
- c. Classification of truck tires.
 - Solid, width.
 - Pneumatic.
- 2. Estimate of Present and Future Traffic.
 - a. Determine tributary land areas.
 - Population on the areas.
 - Products of the areas.
 - Local consumption.
 - Produce hauled to market.
 - b. Intercity traffic.
 - Population centers and distance apart.
 - Probable truck haulage considering type of haulage.
 - c. Rural truck haulage.
 - Point of origin, amount of haul, cost.
- 3. Enhancement of Property Values.
 - a. Zone of influence.
 - b. Rise and fall in values, adjacent, remote.
 - c. Increase in assessable property giving income to state and county.

IV. Study of Finances.

- 1. Financial Status of County as Unit.
 - a. Income of county.
 - Registration of automobiles.
 - Trucks, autos, motorcycles.
 - Classification as to city and rural districts.
 - Assessed value of property.
 - Tax rate for roads, special levies.
 - b. Bonded indebtedness.
 - Type and life of bonds.
 - Roads on which money was spent.
 - Life as compared with life of bonds.
 - Sinking funds, annuities, etc.
 - c. Money available.
 - For road construction.
 - For road maintenance.
- 2. Methods of Financing Construction.
 - a. Federal aid.

- b. State aid.
- c. County aid.
- d. Bond issues by county or state.

V. Study of Local Materials.

1. Location and Classification.
 - a. Old materials.
 - b. New materials.
2. Quality and Quantity.
 - a. Determine by survey and tests.

VI. Selection of Economic System for County.

1. Choose leading roads from service they give or may give.
2. Classify secondary and tertiary systems, determining order of improvement and reasonable amount to spend.
3. Choose type of surface considering traffic and local material along with ability to finance project.
4. Try, if possible, to let the burden come where the benefit accrues.

From the very beginning it was obvious that field data could not be taken in all counties of the state. A choice of counties was so made that proper facilities for study would be offered, and at the same time the data taken would be typical of other counties of the state. Davidson County is the capital county and has one of the best developed county highway systems of the state. The configuration of the roads is radial, and this, too, is typical of such counties as Knox, Hamilton, Shelby and Madison.

Williamson County is one of the leading agricultural counties of Middle Tennessee. The county has a large mileage of highways to be improved. It also has about 85 miles of toll roads and about the same mileage of improved gravel roads.

Maury County has recently purchased the toll roads, making them public property. The county is also entering upon an improvement program of high class road surfaces.

Cumberland County is located on the Cumberland Plateau, is sparsely populated, and has a low taxable wealth. The road problem of this county is typical of a number of sparsely populated counties.

In addition to taking field data in these counties, traffic counts were made in Sullivan, Hawkins, Grainger, Knox, Loudon, McMinn and Bradley Counties. In these latter counties the count was made simultaneously over 190 miles of road. The effort was to discover variations in traffic at stations along one of the leading roads of the state.

DESCRIPTION OF SURVEY

1. Highway Evaluation.

It does not seem necessary to make a survey of the highways in as much detail as is being made by the Interstate Commerce Commission for the railways. Approximate data, however, should be of very great value in a highway transport survey. After inspecting a number of roads the following classification of road surfaces was made, and by inspection the several road surfaces of each county were placed in their respective classes.

MACADAM WITH SURFACE TREATMENT

1. Surface smooth and application in good condition. Either recent application or surface in such condition that two or more years of life may be expected.

2. Surface in wavy condition so that the speed of vehicles is limited to avoid inconvenience to travel; surface sufficiently worn to require patrol to

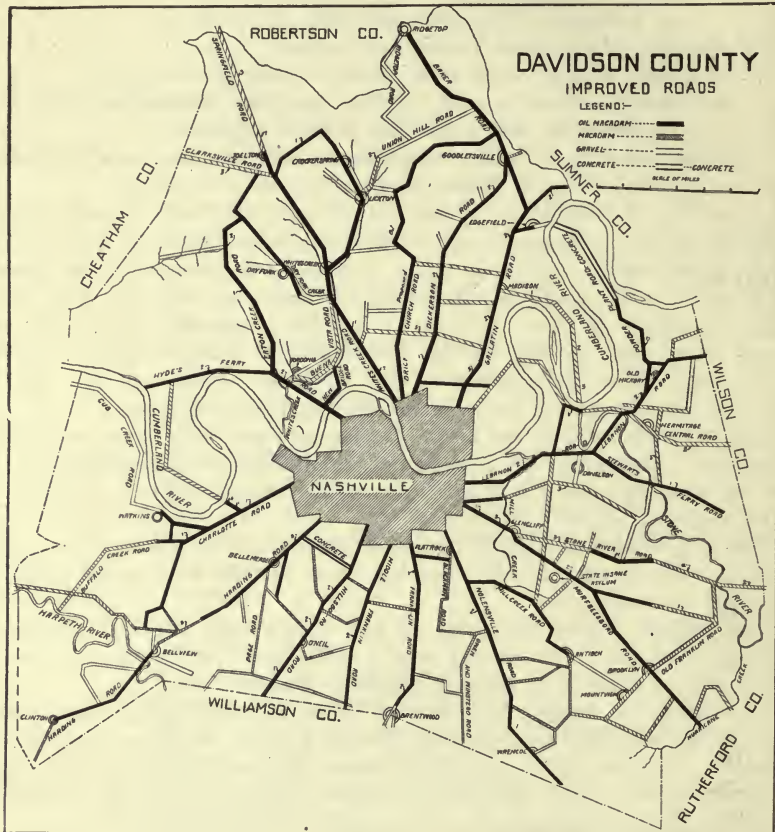


FIG. 1.

keep in fair condition; edge torn, requiring patching to avoid inconvenience to traffic when vehicles are passing each other.

3. Surface in such condition that scarifying and reshaping is necessary before application of new treatment.

(Note: Any surface in bad condition due to pot holes, ruts, raveling, etc., is to be classified with poor macadam class.)

MACADAM SURFACES

1. Road surface in good condition, to proper crown and width. Surface ready for carpet treatment without additional work except possibly brooming before carpet is applied.

2. Surface containing small depressions and a small amount of loose stone. Patching and possibly rolling needed before carpet can be applied.

3. Surface in such state of repair that it must be scarified and reshaped before treatment may be applied. Materials in place may be used with a small amount of additional material.

4. Surface thin and of little value. Practically all of new surface to be

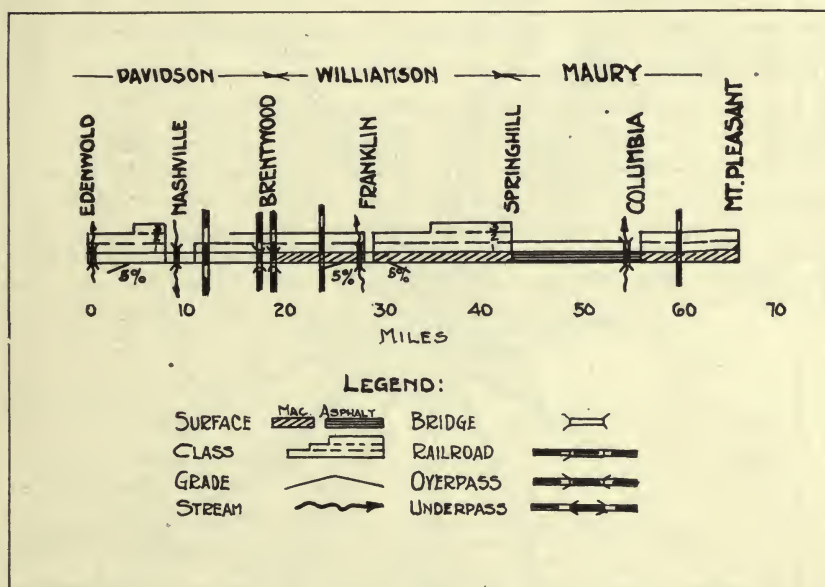


FIG. 2.

of new material. Newly graded subgrade for application of road metal to be placed in this class.

5. Roads of bad alignment, excessive grades or insufficient width requiring such changes that all previous material will be lost.

GRAVEL SURFACES

1. Surfaces in good condition; drainage open, road to proper width and crown.

2. Roads properly graded and which have been surfaced but need new material and reshaping.

3. Graded roads which are ready for surfacing.

4. Roads requiring changes in alignment, grade and width; or roads

where the drainage structures are bad and which will require large expenditures to make them passable with modern traffic.

Fig. 1, for Davidson County, illustrates the method of tabulating classifica-

TRAFFIC COUNT

STATION _____ ROAD _____ COUNTY _____

FROM 6:00 _____ M. TO 6:00 _____ M. 192 _____ CONDITION OF ROAD _____

KIND OF VEHICLE	DIRECTION	6:00 TO 8:00	8:00 TO 10:00	10:00 TO 12:00	12:00 TO 2:00	2:00 TO 4:00	4:00 TO 6:00	TOTALS
AUTOS								
TRUCKS								
BUGGIES								
WAGONS								
TOTALS								
WEATHER								

FIG. 3.

Road..... Station..... County.....

Weather..... Date..... Condition of Road.....

License No.	Time	No. of psngs.	Direction		Distance	Capacity	Width of tires		Make	Kind of vehicle	Residence of owner
			In	Out			Front	Rear			

FIG. 4.

tion data. Fig. 2 also illustrates a method which may be used for giving more detailed information. By such a survey an approximate estimate may be made of the value of the existing system, and an estimate may be made of the cost of improving such a system to meet the present and future traffic needs.

KIND OF SOIL

The only information taken on kinds of soil is that found in reports of the Geological Survey on soils of the counties studied. This information is more general than is desirable for highway purposes, though of considerable value in classifying the general types of soil.

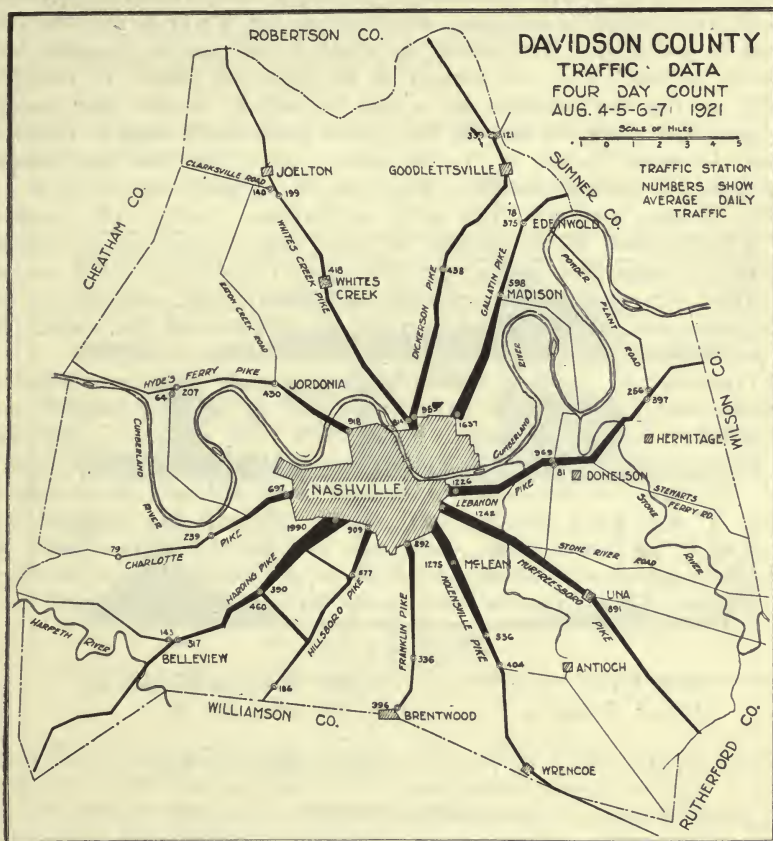


FIG 5.

MAINTENANCE

In all the counties studied, the major part of maintenance was carried on by the gang system, though in Davidson County the gang system is supplemented by patrolmen. In all counties studied, the gang system must be employed. The road surfaces are in such a state of repair that it would be impossible for a patrolman to properly improve and keep the surfaces in good condition. This is as true of Davidson County as any other county. Even though this

county has more than 300 miles of hard surface roads, still there are over 600 miles of district roads which must be improved before a patrolman can properly maintain them. In all the counties studied, the county convicts were used for work on the roads.

THE TRAFFIC

Roads are built to serve the traffic. The first measure of service, therefore, is in the traffic which is going over the road, and which may go over the road during its useful life. To discover the traffic in the counties, counters were placed at a large number of stations on the important roads. In Davidson County the counting extended over a four day period. In the other counties the count was taken for one day only. The traffic blank used in Davidson County is shown by Fig. 3. In the other counties the plan was changed to give more detailed information. Fig. 4 shows this latter form of blank.

Fig. 5 shows the traffic data taken in Davidson County. The width of line is proportional to the intensity of traffic and the numbers set opposite the traffic stations give the average daily count for the year. The average daily count was obtained by comparing twelve-hour counts with twenty-four-hour counts and then comparing averages for August with the average for the year.

In addition to counting traffic, weighing stations were established in Nashville and Columbia. A large number of all types of vehicles were weighed, both loaded and empty. Traffic data were available in Davidson County at eleven stations taken in 1916. The same stations were used in 1921. This gave an opportunity to compare values and note the increase of traffic. It was found that the total volume of traffic had increased 2.91 times, while the motor-drawn traffic had increased 5.2 times. From the traffic data taken, estimates may be made of the total volume of traffic in the counties. These estimates will be given for Davidson and Maury.

Davidson County

Main Pikes	84,660 vehicle-miles per day
District Roads	14,600 miles per day

Total	99,260 miles per day
-------------	----------------------

Maury County

Main Pikes	23,000 vehicle-miles per day
District Roads	12,500 miles per day

Total	35,500 miles per day
-------------	----------------------

In Davidson County 83.3 per cent of the traffic is motor drawn, and of the motor traffic the counts showed that 70 per cent of it is from city-owned cars.

$$99260 \times .833 \times .70 = 57,820$$

$$99260 \times .833 \times .30 = 24,780$$

The registration data show 10,250 cars in the city and 1,750 cars in the country.

Miles per vehicle per year:

$$\text{City} - 57,820 \times \frac{365}{10250} = 2,070$$

$$\text{Rural} - 24,780 \times \frac{365}{1750} = 5,160$$

It is probable that no more than half the mileage of the city-owned cars is on the country roads.

In Maury County 67.5 per cent of the traffic is motor drawn, making the

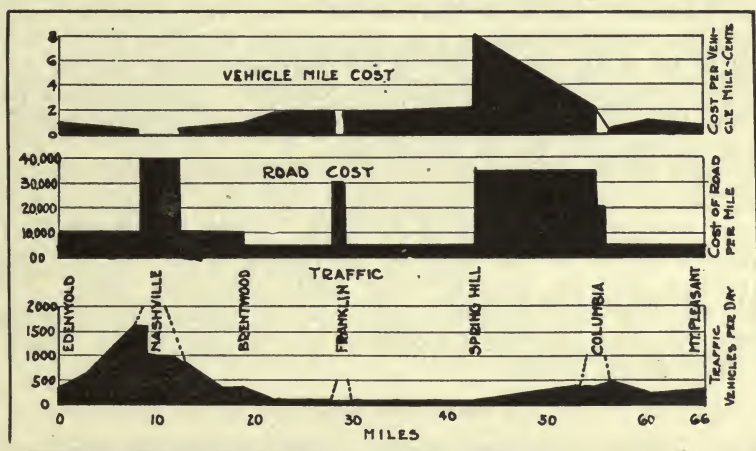


FIG. 6.

total daily motor-drawn traffic 24,000 vehicle-miles. There are 1,836 vehicles registered in the county, making an average annual mileage of 4,771.

The results obtained in this way seem reasonable, though probably somewhat low. A questionnaire in Knox County gave the average annual mileage for autos above 6,000 miles. It will be noted in the above computation that the assumption is made that there is as much foreign travel by the cars in the county as there is county travel by foreign cars. In some cases this would be far from the truth, but in the two counties listed the assumption seems reasonable.

Knowing the total travel in a county and knowing the total expenditure per year, it is very easy to compute the average cost per vehicle-mile. In Davidson County the annual expenditure is approximately \$400,000, and in Maury County it is \$47,400, making the vehicle-mile cost in the two counties, 1.104 and 0.365 cents, respectively. These values give no information as to

the condition of the county highway system, but they do give an indication as to excess or deficiency in funds available for the traffic to be accommodated. The cost per vehicle-mile ranges from 0.2 cent to 8 or 10 cents, depending upon the type of surface, the traffic and the maintenance methods. Fig. 6 illustrates the variation along the roads from Edenwold, in Davidson County, to Mt. Pleasant, in Maury County.

ENHANCEMENT OF PROPERTY VALUES

It is generally accepted as true that property values will increase with the improvement of highways. A number of studies have been made which reach this conclusion. In Davidson County we compared two areas, one being served by oiled macadam roads, and the other by earth roads in not very good condition. We found that all persons interviewed believed that their property had increased or would increase with the improvement of the road surfaces. In the territory served by improved roads the value of the land was estimated to be at least \$50 more per acre than in the territory served by the earth roads. Part of this increase in value may be due to density of population and proximity to Nashville. From the data taken, it seems reasonable to assume that improvement in highways caused the land to increase from \$20 to \$25 per acre.

A rather detailed study made by Prof. C. E. Allred in Williamson County caused him to conclude that Williamson County land increased about \$20 per acre with the improvement of the roads. In some of the districts of Williamson County the land values will not increase as much as \$20. Should the value so increase, property values would more than double. Other factors than highway improvement enter into the enhancement of property values. Two other factors which certainly enter are the intensity of population and production per acre.

STUDY OF FINANCES

It is a comparatively simple matter to obtain the financial status of the counties. The records in the trustee's office show the taxes collected by districts and the resources of the counties by districts. A detailed study of such tax data discloses very interesting results. For example, the assessed value of property in Davidson County ranges from \$37.50 to \$332 per acre. In Williamson County the range is from \$6 to \$193 per acre. The road tax per mile of road in Davidson County ranges from \$47.35 to \$563.10. In Williamson County the range is from \$3.37 to \$283. It is thus seen that the type of service that the taxes will purchase is quite variable. None of the counties studied had an excessive bonded indebtedness. Cumberland County, with a wealth of \$5,634,000, has the highest percentage of indebtedness, the percentage being 4.56. The other counties have a bonded indebtedness of less than 1.5 per cent.

LOCAL MATERIALS SHOULD BE SOUGHT

There should be a greater use of local materials in highway building. Materials always comprise a large part of construction cost. By using local

materials, large economies will often result. The County Highway Departments and the State Highway Department could realize a large saving by properly prospecting and testing local material supplies before contracts are let.

Davidson, Williamson and Maury Counties have an abundance of gravel and limestone. Cumberland County has a large deposit of limestone in one section of the county. In other sections of the county there is a mixture of sand and clay which may be used for road building.

In this survey no effort was made to discover new supplies or develop old supplies. The task of such a survey is a large one and should be undertaken by proper county and state agencies.

CONCLUSIONS

At this time we have not been able to digest all the data taken, but the following conclusions seem to be justified from the study:

1. The method as outlined is feasible and information may be obtained without excessive cost.
2. Approximate data on highway evaluation will be useful in determining operating costs and will also show whether the road system in the county is standing still, being improved or going backward. This information may also be used in determining the cost of the needed road system.
3. The traffic blank, shown in Fig. 3, does not give enough information.
4. On roads where the traffic is less than 700 vehicles per day one counter may get information called for on blank shown in Fig. 4.
5. By counting at several stations on the main roads a close approximation to the total volume of traffic may be made.
6. By weighing the vehicles an approximate total tonnage may be obtained and valuable information as to over-loading will result.
7. Knowing the traffic and the expenditures, approximate operating costs will result.
8. Local needs, in the main, determine what the expenditures should be.
9. On the main roads the traffic will justify high-class surfaces.
10. The taxes now collected are not enough to pay for hard surfaces on more than 25 per cent of the roads in the county systems.

Note: A more complete discussion of the survey is given in Bulletin I, University of Tennessee Engineering Experiment Station.

The Program of the Highway Education Board

By DR. WALTON C. JOHN, *Secretary of the Highway Education Board*

Before going into the details of the program of the Board it may be well to go back and consider the condition of transportation just before the World War. At that time the automobile was just commencing to be recognized as a worthy instrument for the transportation of passengers. It had scarcely commenced to enter the field of transportation of merchandise. Our highways, for the most part, were relatively unimproved. Only in our larger cities and environs were there high-grade pavements to any extent.

With the coming of the great World War, new and constant demands were made upon the transportation facilities of the country, especially the railroads. When the United States finally entered the war it was found impossible to maintain the old methods of transportation. This gave opportunity to the motor truck, which since has been rapidly winning its way to favor. Just as Napoleon said: "An army moves on its belly," it might equally well be said that the American Army and the armies of our allies were moved on the motor truck.

Looking back three or four years we can recall a vivid impression of great convoys of trucks carrying troops and equipment to the centers for transportation to Europe. What was the result? Our roads, which had not been designed for the heavy traffic imposed upon them with this new and heavy unit of transportation, were broken up, as it were, over night. Some of them were pulverized and blown away in dust, but the truck had vindicated itself as a highly efficient instrument for transportation in the time of war, and in view of the lack of railroad facilities proved itself of equal value as an instrument of peace. Thus the great need for improved roads was created and out of this great need grew the Federal aid plans for highway building on a scale more prodigious than at any other time during the world's history. The amount of funds which have become available through Federal aid and the corresponding state and local aid will, including the next five years, run into billions of dollars, comparable with the amount of the National Debt at the close of the Civil War. We can, therefore, imagine the responsibility laid upon the Federal Bureau of Public Roads and the State Highway Departments regarding the right and economic expenditure of these vast sums of money.

BOARD CALLED INTO BEING

Notwithstanding the fact that money was appropriated, it was impossible to find a sufficient number of trained engineers capable of constructing improved highways of such a character as would stand up under the continual grind of automobiles and motor trucks. Out of this demand for trained engineers grew the first call for the creation of an organization which has developed into the Highway and Highway Transport Education Committee, now the Highway Education Board. The great automotive and rubber indus-

tries find themselves likewise perplexed with the new economic situation, and lacking sound data regarding the transportation of goods over the highways and the corresponding relation of highway transport to other forms of transportation. These, with other interests, joined in calling upon the United States Commissioner of Education to summon a National Conference on Education for Highway Engineering and Highway Transport. This was held in Washington, May 14 and 15, 1920, and was well attended by leading highway engineers, economists, leaders in the automotive and rubber industry, and a great many others interested in transportation problems.

After a careful study it was voted that the Commissioner of Education be invited to form a permanent committee to continue the study of the coordination of the many problems involved in highway engineering and highway transport, and to encourage proper research; to lay the foundation for college courses of study in the new field of highway transport, and to hold such regional conferences as might seem best in the several states. The Commissioner of Education, who was named chairman of the committee, appointed the following as his associates: Thomas H. MacDonald, Chief of the Bureau of Public Roads, Department of Agriculture; Col. Mason L. Patrick, Engineering Corps, U. S. A., War Department (since Colonel Patrick's elevation to the Major Generalship, in charge of the Air Forces of the United States, he has been succeeded by Col. F. C. Boggs); Roy D. Chapin, President of the Hudson Motor Car Company and Vice-President of the National Automobile Chamber of Commerce; Harvey S. Firestone, President of the Firestone Tire and Rubber Company and Representative of the Rubber Association of America; W. S. Keller, President of the American Association of State Highway Officials; Dr. F. L. Bishop, Dean of the School of Engineering of the University of Pittsburgh and Secretary of the Society for the Promotion of Engineering Education. During the past year C. J. Tilden, Professor of Engineering Mechanics, Yale University, was Director of the Committee.

INTEREST AMONG YOUTH STIMULATED

The Board in harmony with the policies outlined at the general meeting, has not only encouraged research in highway engineering and highway transport in our universities and colleges, but it has attempted to encourage the youth in the high schools, who are to be our coming voters on the question of good roads, to become acquainted with these problems. This has been done by the means of annual National Essay Contests on the subjects pertaining to good roads and highway transport for students of high-school grade. Due to the generosity of Mr. Firestone, the winner of the national prize receives a \$4,000 university scholarship, the last year's contest having been won by Miss Garland Johnson, of Bridgeport, W. Va., a 14-year-old high-school junior. Miss Johnson's prize-winning essay was published in a recent issue of *Collier's Weekly*. In order to overcome the dangers which beset our children on the highways the Board as a result of the generosity of the National Automobile Chamber of Commerce has been able to offer to the children of the graded schools, 14 years of age and under, about 500 cash

prizes and medals for the best essays on highway safety. And to further stimulate this cause, \$1,500 in prizes has been offered to elementary school teachers for the best lessons teaching safety in the schools. It is expected that this study of the question of safety will tend to reduce the number of accidents and the death rate due to traffic mishaps, which reaches an alarming total each year.

REGIONAL CONFERENCES

The Tennessee Conference, which is being held in Knoxville, is the sixth of its kind held under the direction of the Board in cooperation with the leading universities and colleges interested in the new problems of highway transport. It is hoped that the scientific and technical studies which are presented at such conferences will stimulate the highway engineering officers, the automobile and motor truck users to give much more serious study to the economic problems involved. This will result in a great saving of money to the country and will hasten the new era of prosperity to which the country looks forward with increasing hope.

Highway Hazards

BY M. O. ELDRIDGE, *Director of Roads*
American Automobile Association, Washington, D. C.

Accidents to motorists and pedestrians are occurring annually in appalling numbers on the public highways and streets of this country. Approximately 80,000 persons were accidentally killed in the United States in 1919, of whom about 10,000 were killed as a result of automobile accidents of one kind or another. Unfortunately, about 28 per cent of all the persons killed by automobiles were children under fifteen years of age.

Obviously the trouble is due to increased motor-vehicle traffic. A city of 100,000 population today has more vehicles on its streets than a city of a million population had ten years ago.

The blame for this startling mortality on our highways is charged by some to the speed maniac who cares not for the life or limb of the pedestrian so long as his own skin is unscathed. Others place the blame on the careless pedestrian who thinks that he has a right to use the public streets and highways wherever and whenever he pleases. Still others place the blame on unsafe highway conditions, to dangerous railroad grade crossings, and many other causes.

As a matter of fact, accidents on highways are due to all of these causes, and it is, therefore, desirable that accident statistics be gathered in considerable quantity and detail and that the causes be analyzed with a view to determining where the trouble exists and the remedies which should be applied.

Many facts and figures have already been collected and used in educational and safety week campaigns by which accidents on highways and streets have been greatly reduced. For several years the State of Iowa has collected and published statistics of this sort. Recently the state highway authorities of Maryland made a survey of accidents occurring on state highways in which fourteen fatalities, between May and July, 1921, were classified as follows:

Failure to heed warning at railway crossing	2
Speeding	4
Driving on wrong side of road	4
Reckless driving	4

The Maryland authorities report that careful motorists usually drive with caution in presence of recognized dangers, such as steep grades, sharp curves, and grade crossings, while the absence of such dangerous features gives the driver a sense of security which prompts him to take a chance and yield to the well-nigh universal passion for speed.

SAFETY FIRST CAMPAIGNS EFFECTIVE

According to the United States Census, deaths resulting from automobile accidents in sixty-six cities in the United States have increased from 1,955 in 1915 to 3,808 in 1919, an increase of 95 per cent. During the same

period, automobile registrations increased from 2,453,780 to 7,523,664, or about 215 per cent, which indicates that the death rate from motor-vehicle accidents is not increasing in the same ratio as the number of vehicles.

The Interstate Commerce Commission has for a number of years been collecting valuable information and statistics relating to grade crossing accidents throughout the country, which is one of the greatest single causes of accidents and deaths on the highways. A digest of the killed and injured at grade crossings from 1917 to 1920 is as follows:

<i>Year</i>	<i>Killed</i>	<i>Injured</i>	<i>Total</i>
1917	1,969	4,764	6,733
1918	1,853	5,783	6,535
1919	1,784	4,616	6,400
1920	1,791	5,077	6,868

Thus it appears that there have been killed at grade crossings during the four years 1917 to 1920 a total of 7,396 persons, and killed and injured 26,536 persons. A crumb of comfort may be gained from the fact that fewer persons were killed at grade crossings in 1920 than in 1917 or 1918 in spite of the tremendous increase in motor-vehicle traffic. This is probably due to safety first campaigns carried on by the railroads, automobile clubs, and other organizations and to the elimination of many dangerous grade crossings; to the protection of other grade crossings by gates, watchmen, bells, wigwag signals and other similar devices, and to the placing of crossing signs at sufficient distances from crossings to give ample warning to motorists.

It would seem utterly impossible to eliminate all the grade crossings in the United States, for the simple reason that the cost of such work would in all probability amount to more than the total cost of the railroads. The remedy would, therefore, seem to lie in the elimination of a few of the more dangerous crossings each year, and the placing of watchmen, gates, and other suitable signals at the less dangerous crossings.

A few under-passes already constructed, even on important trunk-line highways, are almost as dangerous as grade crossings because they are frequently placed on sharp curves and at right angles to the line of traffic, thus causing head-on or rear-end collisions of motor vehicles. In future work of this kind, the interests of the traveling public would be best served by so installing these structures as to obtain a clear view of the road ahead to a distance of at least 300 feet.

CAUSES OF HIGHWAY ACCIDENTS

Accidents on highways may be attributed to a number of causes, among which should be mentioned the mania for speed, inefficiency and carelessness of motor-vehicle drivers, defective mechanism, glaring or insufficient headlights and the lack of lights on horse-drawn vehicles, jay-walking, non-uniformity of traffic rules and regulations in different jurisdictions, pedestrians using the right side of the road instead of the left in the open country, non-observance of right-of-way rules, vehicles passing other vehicles on the

wrong side and vehicles passing street cars while discharging or taking on passengers.

The great majority of motor-vehicle accidents are probably caused by the speed crank who is always trying to get ahead of a train or street car or another vehicle. It would seem better to arrive at one's destination a minute or two late rather than to arrive in eternity before one's allotted time.

Many highway accidents are caused by persons who fail to observe the common courtesies or rules of the road which are so well known as to be almost universal in their application. If every motorist would extend the same courtesies "to the other fellow" that he expects the other fellow to extend to him, the highways would be safer for everybody.

Improper lighting of motor vehicles is responsible for numerous accidents, especially on country roads. The blame for such accidents is generally placed on glaring headlights. As a matter of fact, many of these accidents are due to insufficient light to enable the motorist to see where he is going. A headlight which is producing enough light on the road, which it will do if properly equipped, will not bother the other fellow, provided he is similarly equipped. The chief cause of glare appears to be faulty adjustment of bulbs in the headlights. What the motorist wants is light and more light, but he wants it thrown down on the road where it will do him some good and do his fellow-driver no harm.

Among the highway hazards which cause numerous accidents may be mentioned sharp curves where the line of sight is impaired by embankments, buildings, or other obstructions, excessive grades, narrow bridges, slippery road surfaces, dangerous and improperly marked detours, and defective road surfaces and bridges.

Chief among the causes of accidents in the cities appears to be the lack of uniform traffic rules and regulations which definitely prescribe those sections of streets which may be used by vehicles and pedestrians, respectively. Some cities have already enacted ordinances prohibiting jay-walking and requiring pedestrians to cross the streets at crossings in congested districts.

Many well-intentioned but misinformed persons are inclined to place the blame for the majority of motor-vehicle accidents on the motorist. That this is not the case, however, is shown by a traffic study conducted in 1919 by the Department of Health of New York City.

The records of the New York Police Department relating to accidents caused by automobiles were tabulated into three classes: (1) Those caused by carelessness of operators; (2) those due to defective mechanism; (3) those due to carelessness on the part of the person injured, the pedestrian. In the first two classes 800 accidents were due to carelessness on the part of the operator and 700 the result of defective mechanism, a total of 1,500 chargeable to vehicular operation.

Against this figure, it was found that 9,000 accidents were due to carelessness on the part of the person injured, or six times the number caused by carelessness of automobile drivers. Of this 9,000, one-third, or 3,000, were injured while crossing streets elsewhere than at crossings, thus sustaining the A. A. A. contention that, until pedestrian traffic is regulated,

there will be slight decrease in the number of street accidents in which motor vehicles and pedestrians are concerned.

MORE RADICAL REGULATIONS PREDICTED

The time is probably not far distant when motor vehicles using the public streets will be required to slow down at each *properly designated* crossing in order to be able to bring the vehicle to a dead stop under any circumstances before crossing the street, with the other requirement that no pedestrian shall attempt to cross the street at any other than these points. When these rules are adopted and enforced, there will doubtless be a tremendous reduction in the number of accidents and fatalities from the use of automobiles.

Much effective work may be done along this line by students in colleges, by collecting and digesting motor-vehicle accident statistics and by pointing out the remedies. Campaigns of education, safety first weeks and instruction to school children on safety problems will also accomplish much good.

As an illustration, the public schools in the city of Detroit, as a result of efforts made by the Detroit Automobile Club, have for the past three years been teaching safety problems in the public schools in connection with health education. During the first year in which such work was carried on, accidents to school children decreased 5.5 per cent. During 1920, accidents to school children decreased 29.7 per cent over 1918.

With the ever-increasing number of passenger cars and commercial vehicles, the problem of handling traffic on the highways is becoming as important as the traffic problems of the great trunk-line railways, and sooner or later the highway departments of the different states will doubtless find it desirable to establish traffic bureaus, presided over by traffic engineers who will, in cooperation with the construction, maintenance and bridge engineers, handle all problems relating to traffic.

Lack of uniformity in the traffic laws and regulations of the various states and cities is doubtless responsible for many accidents, for the motor vehicle has blotted out state lines. To overcome this difficulty, a committee representing the American Association of State Highway Officials, The Motor and Accessory Manufacturers Association, National Automobile Chamber of Commerce, National Automobile Dealers Association, The Rubber Association of America, The Trailer Manufacturers Association of America, and the American Automobile Association prepared some time ago a proposed uniform vehicle law.

While this law may not represent the last word in motor-vehicle regulation, still it contains the best thought of the best informed men in the country on this subject. The fundamental principles laid down in this law have already been incorporated in the laws of some of the states, and it is believed that if these principles were generally adopted throughout the country it would go a long way towards solving our traffic problems and preventing many accidents.

Cost of Motor Vehicle Operation

BY MAJOR I. C. MOLLER

New York City

Motor truck operating costs, like all other cost figures, are of value in many different ways according to the use to which they are to be put. In this case we are principally interested in the effect of improved road surfaces, grades, and curves, upon the cost of hauling merchandise.

The character of road has a very material influence upon motor truck operating cost. To appreciate this it may be useful to consider the items which go to make up a complete operating cost in the order of their importance and the degree to which they are affected by road conditions. In general, the following grouping of items by percentages may be considered a fair relation:

	<i>Per cent</i>
Gasoline	23.8
Driver	20.0
Tires	17.1
Amortization or depreciation	12.7
Maintenance and repair	6.7
Insurance	6.5
Garage	5.5
Running supplies	2.7
Interest and state license	2.7
Lubricating oil	1.2
Washing and polishing	1.1
	<hr/>
	100.0

Of these items the following are affected by road conditions:

	<i>Per cent</i>
Gasoline	23.8
Tires	17.1
Amortization or depreciation	12.7
Maintenance and repair	6.7
Washing and polishing	1.1
	<hr/>
	61.4

It is thus seen that road conditions will have an effect on items constituting 61.4 per cent of the entire cost.

Road conditions, however, will have other effects of great importance upon the cost of transportation. Well-constructed roads permit the economical operation of trucks of larger capacity, which in itself represents a very important economy, since trucks of large capacity are capable of hauling

goods at lower unit cost than those of small capacity. A large-capacity truck represents a smaller investment per unit of capacity which involves lower unit charges for amortization, interest and insurance. A large vehicle, while it costs more per mile to operate, does not involve an increase in operating cost directly proportional to the additional load which it carries, and consequently all maintenance and running charges are proportionately less per ton-mile. Thus, in a recent comparison of operating costs it was found that under exactly similar conditions a 2½-ton truck could travel 100 miles per day, delivering 25 tons; the 3½-ton truck could travel 90 miles a day, delivering 33½ tons; the 5-ton truck 80 miles per day, delivering 40 tons, and the 7½-ton truck 70 a day, delivering 52½ tons. The total cost per day of these vehicles was, respectively, \$21.20 for the 2½-ton truck, \$26.41 for the 3½-ton truck, \$26.36 for the 5-ton truck, and \$27.40 for the 7½-ton truck. But the cost per ton-mile was: 2½-ton, 16.9 cents; 3½-ton, 15.7 cents; 5-ton, 13.1 cents, and 7½-ton, 10.4 cents.

A thorough study of motor truck operating costs is of value to highway engineers aside from its relation to highway economics, inasmuch as motor trucks are in extensive use in highway building and their use in this field will undoubtedly continue to increase.

ANALYTICAL DISCUSSION OF COST ITEMS

What are costs? Defined simply, costs are the expenses incurred by a truck either when running or idle. Merely to say that it costs \$25 a day to operate a 5-ton truck will not convey anything comprehensive. Should this statement be qualified with the amount and kind of work done, the cost figure will have a different aspect, for by giving the work a value a person is in a position to judge the cost on the basis of earnings and performance.

Motor truck operating costs are commonly divided into three classes: fixed, maintenance, and running charges. For complete costs it is necessary to add administrative and operative overhead. As overhead is really part of the accounting of the business proper it will not be discussed here.

Fixed charges, with one exception, are those that do not vary from day to day. They go on whether the truck is in use or not. The exception is amortization. The other fixed charges are interest, insurance and license fee.

AMORTIZATION IS SELF-MAINTENANCE

Since all machinery wears out in time and never can be liquidated at its real value, depreciation should be allowed for, otherwise the time will come when the owner will find that his investment has vanished. To allow for this, a depreciation charge is made so as to build up a sinking fund from the earnings of the truck which will replace the investment when the truck is worn out. This method of self-maintenance is called amortization, a word which means to live perpetually. Amortization is also defined as a pro-rated renewal charge. By amortizing the investment it is constantly kept alive so that for every mile that affects its life, a certain sum of money is set aside. With an ideal amortizing method it will be found that the amortization fund will equal the original investment at the time when the

truck is worn out and no longer economical to operate. Motor trucks are commonly amortized on two bases, time and mileage.

Years ago, when the motor truck was still in the experimental stage, it was quite proper to amortize motor equipment on a time basis, since the vehicle became obsolete within a comparatively short time. Today, however, the basic engineering principles are practically established and obsolescence is no longer as important a factor as it was. The accepted modern method of amortizing a motor truck is on the *mileage* basis. Experience has shown that some trucks are good for more than 300,000 miles, many records of such mileage being on file. Conservativeness, however, places the life of a truck, for amortization purposes, at from 100,000 to 150,000 miles.

By employing the mileage amortization method, every mile the truck travels is paid for, theoretically at least, and the sum invested. In this way the original investment is gradually reduced so that at the end of the estimated life of the truck, there has been set aside an amount sufficient to replace the equipment when necessary. By investing the amortization fund an income is brought in which should be credited to the truck. In actual practice this is rather complicated and to make it more simple this income is credited to interest by charging interest at the legal rate on the average investment. Amortization is computed on the basis of net investment, that is, the total investment, *less the cost of tires*.

HOW TO PROTECT VEHICULAR INVESTMENT

Buying a truck is making an investment. It is necessary to take from the business, either as cash or credit, a certain sum of money. Like all sound investments this money should have an earning capacity of at least the rate it would cost to borrow a similar sum.

Interest, therefore, should be charged at the legal rate on the average investment, that is, the total investment, divided by 2. Charging interest on the total investment would be proper if the truck were credited with the interest earned by the sinking fund. But, inasmuch as the interest earnings of the sinking fund are not carried as a separate item, it would bleed the investment to charge interest on the total investment. Since the amount of the total investment decreases proportionately as the sinking fund increases, the sum of both will always equal the original investment.

Whether insurance is carried with an insurance company or by one's self, the cost should be charged to the truck.

Maintenance charges are partly dependent upon time and partly upon mileage. This group also has one exception, the garage charges. The remaining items coming under the heading of maintenance are: tires, chassis repair, painting, chassis overhaul, lubrication, inspection and adjustment. It will be noted that each item is basic in its effect upon the condition of the truck—hence the term “maintenance.”

The garage cost continues whether the truck is working or not. It is governed solely by the time factor. Garaging charges are determined in several ways, rental, apportioned according to size of vehicle, and type of service. If space and service is bought, each truck should be charged with

the expense it incurs. If the garage belongs to the operator, the trucks should be charged with the standard items that make up the cost of owned property, such as interest, taxes, insurance, upkeep, light, heat, and power.

KEEPING DOWN REPAIR BILLS

It was stated in the discussion on amortization that this item was calculated on the basis of net investment, which is total investment less cost of tires.

As the exact mileage of a tire cannot be determined when it is new, and as it is advisable to fix a per mile cost so that the cost of operating may be approximated within narrow limits, two methods are used in making the estimate. The first, and more conservative, method is to divide the original cost by the adjustment mileage, usually 7,000 miles; the second, and more common, method is to divide the original cost by the mileage based on experience.

In the case of pneumatic tires, however, no account is taken of the cost of repairs. Therefore, before a true tire cost can be determined, it is necessary to know the actual tire mileage and the repair charges. These can only be had after the tire has served its economic life. Actual tire costs can, therefore, only be determined after the tire is finally disposed of.

The cost of repairs, like tires, cannot be computed exactly until the end of a definite period of time, usually one year. But, as in the case of tires, it is advisable to estimate the cost. Some users charge against a truck the repair cost at the time such repair is made. This practice will result in a high cost per unit of work at one time and a low cost at another, besides being an erroneous method of making such a charge. If the time that elapses while a part is wearing away could be determined, it would be proper to charge the cost to the truck over that period of time, but as this cannot be done with any degree of certainty the fairest and easiest way is to distribute the total yearly cost in proportion to the monthly mileages.

Just as a person needs a periodic visit to a dentist to prevent excessive tooth trouble, so a motor truck needs a periodic overhaul. Application of this rule will result in lowered repair charges, for the overhaul will disclose conditions which, if cared for immediately, will cost comparatively little to remedy, but which, if allowed to continue, will necessitate heavy expenditures. Inasmuch as the benefits of the overhaul are extended over a long period, the cost should be distributed over the same period and in proportion to mileage.

Running charges are aptly named. They are the costs that are incurred only when the truck is running. They are: gasoline, oil and supplies, such as cup grease, transmission oil, kerosene, and driver's and helper's wages. These items usually total nearly half the total cost of operating a truck. It is, therefore, here that one must keep especially close watch if economy is to be maintained.

From the very inception of truck accounting, there has raged a fierce verbal battle over the term "unit-mile." Defined, unit-mile means the carrying of a unit a distance of one mile. It makes no difference what the unit is.

In excavating work it might be the cubic yard, in coal hauling the ton, in department store work the package, in dairying the 40-quart can, in cooperage work the barrel.

Most authorities now agree that the unit-mile should be computed by *dividing the average round trip distance by 2 and multiplying the quotient by the total tonnage.*

By adopting a uniform method of computing the unit-mile, operators, in comparing costs, speak a common language.

DISCUSSION OF COST SYSTEMS

Ever since the motor truck's invention, students have diligently studied costs. Scores of cost systems have been devised. Tire and truck manufacturers have employed expert accountants to tabulate statistics and compile systems, advertising literature has glowed with impressive arrays of figures, but nowhere could two separate cost statements be directly compared. No two estimates included all the items necessary or computed them in quite the same way. Nearly all compilations and systems showed, on study, that certain important items had been omitted. Nowhere were the methods of figuring depreciation, interest, overhead, or performance uniform.

Finally a series of Truck Owners' Conferences held in a dozen or more of the principal cities of the country during the past five years brought forth the National Standard Truck Cost System. Since its initial appearance, truck and tire manufacturers have abandoned their own systems to adopt the new. Even so impartial an organization as the National Automobile Chamber of Commerce, the official automotive vehicle manufacturers' organization, has, in recent months, adopted the system as standard for the motor truck industry.

One may advisedly ask how the new standard system differs from its unsuccessful predecessors and why it has succeeded where others have failed. Primarily, its success is attributed to the fact that it originated at a conference at which were many experts with many points of view. It was not produced as a business enterprise, but solely as a service to operators of motor trucks and is distributed at the cost of publication.

In itself, the system represents a distinct advance over any similar attempt, not only in its origin and distribution, but in many of its accounting features. Old moss-encrusted traditions of motor truck accounting have been eliminated. It is not permanent in form, but is subject to annual revision by a committee of experts representing varied interests, so that it may be kept up to date and accommodated to changes in conditions as time goes on.

This National Standard Cost System is but one example of the astonishing degree to which the automotive industry has developed standardization. Standardization of details of design, materials, manufacture and business procedure has been a determining factor in the production of reliable, economical highway vehicles. These are vehicles responsible for the tremendous strides which have been made in highway design and construction in the last fifteen years. The motor vehicle industry may be said to have created, from mere pygmies before its advent, two industrial giants, the oil industry

and the highway industry. No industry can grow and flourish that does not serve the public well and serve harmoniously with other industries. Let us have standardized highways, standardized in harmony with the vehicles for which they are built, to the end that the combination of vehicle and road will serve the public so well that these twin industries will quickly attain the magnitude for which they are destined.

The Living Road

BY PYKE JOHNSON

National Automobile Chamber of Commerce

If there is any one fact which should be impressed on the people of America today it is that we can no longer think of the highway merely as a material thing. The highway is a living force which serves to bind the people of this country more closely together, which stamps out isolation and heightens our standards of living. Into its building and use go all of the elements of romance and adventure which the railroads had in the olden days, and it is only as we emphasize anew these phases of the highway question that we can hope, first, to instill an *esprit de corps* in the men who are carrying on the work today and, second, to appeal to the youth which will cause him to turn to the work tomorrow.

How many men are there who can look back to the time when as boys they sat on the old rail fence watching the trains go by and pictured themselves as the ones who would handle the throttle of the engine in the future? How many men are there today who have read far into the night with bated breath the stories of those days of adventure when the pioneer gangs of the railroads broke their way through the wilderness for the steel rails to follow, and how many men are there today who realize that in highway transport they have at their very threshold the same opportunities for romance and adventure, the same opportunities for civic betterment that the railroads carried with them in the old days?

How many men know that today the road highway gangs of the states and the Government are traveling on snowshoes in the northern country, surveying the way for the highways to come; that other gangs are hanging suspended from high cliffs over rushing waters that the highway may be broken along the canon's side; that throughout the western country men are forcing their way through virgin forest in order that means of communication may be opened up? How many men know that in the use of highways China is finding a means to the prevention of famine, Brazil is opening up a vast new empire of hard woods and produce, while in our own country on every side the building of new highways is infusing new life into communities deadened by loss of trade transferred to other communities more fortunate in their transportation?

TRANSPORTATION A FACTOR IN PROGRESS

Romance and adventure await the pioneer in highway transport on every side, whether he go abroad or whether he search about him in the urban or suburban fields of the United States.

It is these things which we must impress upon our road builders and our students, and it is this broad field of opportunity which it is hoped to sketch out somewhat in what is to follow.

In order to obtain an intelligent understanding of highway transport today, it is perhaps necessary to review briefly the whole question of transportation. It has been well said that civilization follows in the wake of transportation, and for affirmation of this it is only necessary to go back to that day in the far distant past when the man of the family first discovered that he could ease his load by pushing a log underneath it. From that time on down through the ages the rise or fall of empire has depended upon transportation. Phoenicia ruled because of its mastery of the waves. The Venetian cities, the Hanseatic League, the modern empires—all owe their position to their communication facilities. It is only necessary to consider the plight of Russia to realize what the reverse side of the picture brings with it.

In our own country transportation has always been a decided factor in our advancement. Those who recall the story of the first settlement of the United States know that postal development came first because of the need for retaining communication with the mother country. Inland waterways were the first channels of communication with the interior, and these were followed by the beginnings of a national highway system in the early construction of the National Pike. The advent of the railroad checked this development, and for a period of more than a hundred years we find that the economic zones of commerce in this country have depended largely upon the railroads, which, generally speaking, pushed from east to west and from north to south.

In all of the thousands of years of development of transportation there was no real progress in highway transport until the advent of the motor vehicle twenty-six years ago. Until that time the transportation vehicles of the ancients were practically as efficient as those of the modern farmer. Searchers in archeological records of the past discovered in a tomb four thousand years old a wheel with a demountable rim, and aside from a few refinements in the wagon and a better breed of stock no real advancement was made in all this period. Then came the motor vehicle. Twenty-six years ago there were four of them in the United States. Six years ago there were a million. Today there are nine and a quarter million cars in the United States, or one to every eleven persons or to every two and a half families. In many states the number is so great that the entire population of the commonwealth could be transported at one time in motor vehicles. What the future may hold for further development no one can say, beyond making this one statement, that every normal man and woman is a potential prospect for the automobile salesman because of that inherent desire for individual transportation which first finds its expression in the youth sitting on the rail fence watching the trains go by.

THE IMPONDERABLES MUST BE COUNTED

In this revolutionary development of modern highway transport we find influences and effects which go far beyond the mere economic phases of living, important as they are and far-reaching as they may be. The first effects to be observed are what Prof. W. K. Hatt has called "the imponderables," those influences which cannot be readily translated into dollars and cents, but which

reach deeper into the life of the country than those aspects which lend themselves to ledger treatment.

Through the use of the motor vehicle the city man of today finds it possible to live in the country, and as the highway is improved we are moving forward to an entirely new and as yet not fully understood development of our cities which will gradually wipe out the slums as the need for a concentrated business section is found less imperative. The day is not far off (there are already evidences of it in England) when manufacturing plants will be moved into the country to avoid the congestion of the city, thus making possible a plot of ground for each workman and his family.

On the other side of the picture the farm is freed from the shackle of isolation which has in the past made life almost unbearable in its drab monotony for the farmer's wife. Today the farmer of Iowa is as familiar with the problems of the farmer of Vermont as were farmers living in adjoining counties twenty years ago. Distance has been eliminated and while we may point to the broadened marketing possibilities, the increased real estate valuations and those other physical aspects which follow in the wake of the improved highways used by the modern vehicle, the real change which has been wrought is in the improved social conditions of the country.

The owner of a motor vehicle and his family are more in the open than the man of a quarter of a century ago would have ever deemed possible. They see more of their country. Their educational facilities are better because of the consolidated schools, made possible by the community bus, and their possibilities for recreation, which is just as much a part of living as the working side, have been increased a hundred-fold.

TRANSPORTATION—A FIFTY-BILLION-DOLLAR INDUSTRY

However, there are those who prefer to consider these questions from the standpoint of their effect on economics, and for this class I would suggest that what we are dealing with here today is a fifty-billion-dollar industry—transportation. On the one side, or rather as one link in the chain, the rail lines are valued at twenty billion dollars. As another link, the highways are valued at twenty billion dollars, and here the word highways is used to include the value of the highways and the vehicles going over them; then we have electric lines, our marine shipping, canals and forms of electrical communication, reaching another ten billions of dollars. All in all, a sum greater than twice the entire debt of the United States and almost equal to the value of all of its manufactured products for the past year.

What is the future of this great industry? What are the problems which it brings with it? What is the field of opportunity which it affords to the youth of the country? Twenty-five years ago the major problems of transportation seemed to be solved. The imposition of a vast, heavy mode of traffic on our highways, with its enormous development and its immense requirements of all kinds of raw material, its acceleration of all other forms of industry, have changed all this. New and intricate questions are present from all sides, and it is perhaps enough for the purpose of this discussion to indicate only a few of the more important.

PROBLEMS FOR FUTURE DEBATE

We must fit anew the vehicle to the highway over which it travels. In France, for example, a law has recently been passed which says that 839 pounds per inch of running tire shall be the maximum for the load on each wheel of a vehicle. Is this the standard which is to be followed in this country in the future? The question is one that involves a wide range of research into many phases of economics.

The first question to be answered is whether there is need for a highway in any given location. Does the economic welfare or the imponderable benefit to be derived by the community require its construction? What do the surveys and traffic data show? What changes should be made in the highway itself? What saving can be effected in the traffic over the highway through new gradients, banked curves and other refinements of modern highway construction to reduce tractive and power resistance? What means shall be found for the financing of this undertaking, larger than any other domestic activity of the Government? Political boundaries are no barrier to the cruising radius of a motor vehicle. A local community cannot be expected to bear the full expense of maintenance of rights of way for travel which might originate and end entirely without its jurisdiction. From the standpoint of the general public, is it well to thrust a burden of taxation upon a unit of transportation which in one of its aspects alone, that of the excise tax imposed by the Federal Government, reaches a total today greater than all of the tax paid by all of the corporations in the United States prior to 1916? How far is it economic to go in the imposition of motor registration fees, \$108,000,000 of which have been collected for the first six months of this year, according to the figures of the Bureau of Public Roads, or, putting it another way, \$6,000,000 more than was collected throughout the entire year of 1920; always remembering, however, that collections are far greater in the first half than in the last six months of the year?

What is to be done regarding the administrative control of the highway, both in construction and maintenance as well as operation? Can this question be left long a local unit when, as indicated, it extends beyond local bounds? It would appear that systems of highways will be necessary. How are these systems to be finally selected and classified?

The question of traffic control has become a major one in many cities. It extends also to the rural use of the highway. It involves even the very physical contours of metropolitan development and always it carries with it major questions of safety which must be solved.

Then we have again that other question of the inter-relationship of transportation. What new forms of development are we coming to in intra-state traffic? Is the terminal to be continued? It appears that the modern development of the motor truck is to supplement the rail line, to take from it those short hauls which have been unprofitable, or perhaps for the railroad itself—and this seems a more logical conclusion—to use both forms of carrier. What is the field for this development? Where do the highway transport

vehicles stand in relation to the waterways and the electric lines? All have their economic place. The question is its development.

So the inquiry might be carried on—questions of construction, of maintenance, of operation, of financing operation—all these point heavily to the none too plentiful resources in trained men available today.

Thousands of men will be needed in the future in all phases of this great problem of highway transport. The field is a vast one, limited only by the range of human communities. It transcends the question of development of this country. It penetrates into every section of the globe. In it is afforded a place for the young man and a place which calls for service of the highest type, and it will not be until we have arrived at a thorough understanding of these questions of the development of highway transport that we can hope to reach the ideal of a quickened America which only the highest type of transportation facilities can afford.

A Maintenance Plan for Tennessee Highways

BY BEN L. CUNLIFF

Maintenance Engineer, Tennessee Department of Highways

In organizing a Maintenance Division in the Department of Highways, and in planning and carrying out a maintenance system throughout the state, we are limited at present by several factors, one of the main ones being lack of sufficient funds in both the state and county treasuries to enable us to carry out the system as we would like to see it carried out.

Considering this main, limiting factor, it devolves upon us to get the utmost efficiency out of the funds that are available or can be made available, and it is with this in mind that the following plan for a maintenance system in Tennessee has been worked out.

Funds will be made available for the proper patrol maintenance on those state and Federal aid highway projects which the state has contracted to maintain and the maintenance of these highways or sections of highways will merely amount to a part of the routine duties of the Maintenance Division. I might state in passing that it is our intention to keep these sections in first-class condition always, as an example or model for the rest of the highways.

These sections, so far, comprise but a very small percentage of the whole system in the state. The state and Federal system of main trunk lines consists of about 4,500 miles, and the inter-county-seat highways consist of a little over 6,000 miles, making a total of over 10,500 miles of highways in the state system.

At present the rate of progress in new State and Federal Aid projects is limited by congressional appropriations to not more than 500 miles per year, hence it can readily be seen that considerable time will elapse before the higher types of construction can be applied all over the system, and the demand for "Good Roads, Now" makes it imperative that something be done to save and improve the roads we already have.

In only a very few counties in the state is there even an attempt at systematic maintenance being made. The usual method used by the counties is to wait until the road has worn out and has become almost impassable, and then appropriate some money to "work" the road. On some of the main traveled roads this "working" becomes necessary two or three times a year, and the method in almost all cases costs the county far more than an efficient patrol maintenance system would cost.

Our first idea, then, is to promote patrol maintenance and to educate the officials and the public to the economy and efficiency of a patrol maintenance system, in which the highways are divided into sections of from 4 to 10 or 12 miles, with a patrolman on each section, the patrolman being assisted when necessary by maintenance gangs working out from the county seat.

A CONSTRUCTIVE MAINTENANCE SYSTEM

The system we propose is not only a maintenance system—it is more than that, and might properly be called a constructive maintenance system, for the patrolman will be charged with the gradual improvement of his section, in addition to the maintenance of it. The improvements will consist of widening the shoulders and the road bed, installing better drainage where necessary, improving the type of surface, when possible, by the use of local materials. For instance, in West Tennessee there are hundreds of miles of clay roads that can be made into sand-clay roads and can be thus improved by the patrolman, or, where creek or bank gravel is available, a clay road can be turned gradually into a gravel road by the patrolmen. Finally, the depth of the wearing surface can be gradually increased.

Thus the patrolman will not only be able to keep his road open for traffic, but as the traffic increases he will be able to keep up with the increase and a little ahead of it, and the counties, instead of getting behind farther every year, will thus not only have maintained their roads, but will have better roads each year than the year before, and the cost will be no greater, but probably much less.

Now, as to the application of this idea. If we were to go to the county officials, and arbitrarily tell them to adopt this plan, we would most likely be met with a refusal just on general principles, so, instead, we are telling them about the plan and offering the services of an experienced maintenance engineer, should they request his services, who will go over their county highway system with them, lay out, and estimate the cost of a patrol maintenance system which will be within reach of the available funds of the county; assist them in making out a budget that will take care of the system throughout the year; and, after the system is adopted, assist them in establishing the patrols and instructing the patrolmen, and then make frequent inspection to see that the system is properly carried out.

Naturally there will be some counties which will be slower in taking up the idea than others, and in those counties especially, an actual example of patrol maintenance will go a long way toward the adoption of the entire system. This brings us to the last feature of the plan and the adoption of it will mean, for the entire state, a well-maintained trunk-line system, and it will incidentally mean the elimination of much of the discontent among the larger counties over the distribution of the automobile tax fund.

WHERE THE AUTOMOBILE TAX GOES

The automobile tax now is collected in all the counties and turned over to the state. Half of it goes to the State Highway Department, and the other half is then divided evenly among all the counties, to be spent by the counties under the direction or with the authority of the State Highway Department. To date the department has granted permission for its expenditure on the various local county roads, and in the smaller counties it has been scattered out around the districts, used, and forgotten. It is now proposed that this fund shall be used, in the counties, primarily for

the proper patrol maintenance of the main trunk lines through the counties, thus assuring the automobile tax payer of a just return for his taxes in an improved state system of roads that he can and will use, and thus assuring the counties of the proper maintenance of their main highways, for almost invariably the trunk line systems form the main highways in the counties through which they run.

In most cases the trunk-line system will not require the expenditure of all this fund, and in these cases authority will be given for use of the balance of the fund on other roads after a budget is made which will take care of the trunk-line system.

The Maintenance Division and the Maintenance Plan are both in their infancy in Tennessee, but we feel that with the help and cooperation of the counties and that by helping and cooperating with the counties we can establish a system of well-maintained roads in Tennessee and actually get "Good Roads, Now."

Discussion

W. R. Neel, State Highway Engineer, Georgia Highway Department, said: "We adopted the policy of taking over for maintenance the roads as we constructed them. We have been given the entire automobile license fees to use in the maintenance of these roads. We now have turned over to us, by recent legislative action, 5,500 miles of road, and we are studying what we are going to do with 5,500 miles of road, 50 per cent of which are unimproved, and satisfy the public. We have been preaching maintenance to the counties, little thinking that we would suddenly have this problem thrust upon us.

"We have divided the state into eleven sections, or divisions, about 550 miles to the division. We have adopted not only the patrol system, but the gang system as well—a combination of both. We will have in each division a heavy maintenance organization. We expect to have three gangs properly equipped with heavy equipment—big tractors, road machines, scarifiers, trucks, etc. Then we have divided the 550-mile maintenance division into 50-mile sections and are organizing a patrol on each of these sections, placing one man in charge with five men and one machine operator on each patrol section. The 50-mile sections will be equipped with light equipment, such as road machines, tractors, trucks, scrapes, etc. On the first of the year we will take over this 5,500 miles of road and have the complete equipment in operation.

"We did not wish to pay the entire amount out of the first year's funds for all of the new equipment. We found that it would take about \$700,000 in addition to the equipment the Government had given us to equip fully the entire organization, so we made arrangements to buy this equipment and pay for it in three years. The machinery dealers first investigated how we intended to handle that equipment. We explained that we had three expert mechanics who must first certify that the man handling each piece of the equipment has had sufficient experience to take intelligent care of it. We

also explained that we would have inspectors always moving over the state to see that the equipment was being properly maintained. After this explanation they readily agreed to give us the same price as if we were to pay cash for the equipment."

W. N. Gladson, Dean, College of Engineering, University of Arkansas, said: "Two and one-half years ago our state, through the influence of the governor, agreed to a policy which would call for an appropriation of \$100,000,000 on the highways of the state. We have done a great deal of construction and we have made a great many mistakes. If we have profited by our mistakes, however, they have not been too costly.

"In my opinion, our greatest problem is to get highway engineers who are conscientious, high-class engineers, who are working not merely for dollars and cents but for their own reputation. It has been said that a doctor can bury his mistakes, but an engineer must live with his. Our state made a grave mistake in improving our roads under the district law, in which each district is a unit in itself. The road belongs to the district and that district may maintain the road or let it go to pieces. Our Highway Commission has not had enough authority in building the roads and in determining the character of the roads and where they should be built. It has not had the authority to see that the roads were maintained. Many farmers were led to believe that after the road has been built it will be there forever without any more cost, when, in fact, the roads we are building, largely gravel and macadam, will be worn out before the bonds which were issued for their construction are retired, if they are not properly maintained.

Justifiable Expenditures on the Highway Program

By H. G. McGEE

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Suppose we assume that a highway improvement is worth only as much as its returns in service exceed its cost. Suppose we also assume what may be equally true: that for any improvement for which returns will exceed cost, we pay an unnecessary premium to do without it.

An estimate of returns and of cost for a proposed improvement, then, will indicate whether it is worth building or not. Similar estimates for all the roads in a district will give us a construction program, starting with the most worth while, which offers highway transport its best opportunity to serve and to prosper.

Fairly reliable cost estimates form a routine part of every engineering report. What are the expected service returns which are equally important in judging the appropriateness of a proposed improvement?

The following figures are offered as evidence of magnitude rather than precise measures of value. If they serve only to separate the certainly unprofitable road investments from those possibly profitable, they will be a step in the right direction.

For convenience, suppose highway traffic is divided into three classes, viz.: (1) through, or intercity; (2) rural, or local; and (3) terminal, or interior. If the returns for each of these three classes are estimated rationally and then added together, the total ought, by the laws of chance, to come closer to the true return than will a blanket estimate of the whole.

THROUGH OR INTERCITY TRAFFIC

Any highway improvement worth paying for will reduce the cost of operating vehicles over it. Since the total savings for any improvement comprise the product of the saving per vehicle multiplied by the number of vehicles, volume of traffic and unit economies are equally important.

Other things being equal, it seems reasonable to assume that there will be more highway traffic between large places than small, and that there will be more traffic between places nearby than those far apart.

Wellington's historic study of the economics of railway location points out that each individual is a potential producer of traffic with each other individual on the same line. Over a large area, he states, traffic would therefore vary with the square of the population. The 1920 Statistical Abstract of the United States indicates that the number of railroad passengers carried has increased from 1890 to 1918 almost exactly as the square of the population of continental United States, due allowance being made for periodic business booms and depressions; freight has increased from about 10 tons per capita to over 20, perhaps a third more than the square of the population; ton-mileage 50 per cent more than the square. This pyramiding of transportation demands ought to be cheering to motor interests

which may be worried by "saturation points." But to get back to the highways.

In 1918 Cleveland had a population of about 750,000, and Akron 160,000; in 1920 Cleveland had 798,000, and Akron 208,000. If highway traffic does vary with the product of populations connected, the 1918 traffic on the one paved road connecting the two cities would be to the 1920 traffic as 120,000 is to 166,200. Actually, passenger car traffic rose from 6,586 per week to 9,450, less than 4 per cent more than would have been expected; truck traffic rose from 1,438 cars per week to 2,740, 38 per cent more than would have been expected. But freight conditions were not constant: the 1918 count was made after about two years of freight-car shortages and embargoes; the 1920 count at the end of four years of such stimuli to highway transport.

There seems to be no such simple way to count the traffic between two cities and then let them grow farther apart or nearer together and count them again. However, it is possible to figure the population products of all the cities along a given road, and, after dividing the products of each pair by the distance between them, add all the resulting quotients together and compare this sum, which we have called the "traffic factor," with counted traffic. For most roads there are more than two cities, one on each side of the counting point, to be considered; and, in the actual comparisons made, traffic between cities more than 50 or 60 miles apart was assumed to be so small it could be safely neglected.

Four counts on three paved roads have been so compared. These comparisons indicated that in northeastern Ohio an average of 45 tons of freight and seventy passenger cars may be expected to travel the road annually for each unit of traffic factor, populations being expressed in thousands and distances in miles. Variations from this average on different roads and at different times indicate a probable error of 15 per cent in this result.

It may be interesting to compare this figure with the average of less than carload lot rail shipments. A study of several annual reports of railroads indicates that about 5 per cent of the total rail tonnage comes in l. c. l.; for the country, then, the average would be about a ton per capita annually. The total of the traffic factors of all highways extending out from Akron, excluding traffic through the city, is 9,514, indicating a potential highway freight movement of 438,000 tons in or out annually. More than half of this potential highway movement is due to the proximity of Cleveland. In other words, in Akron's peculiar situation we may provide for nearly twice as much highway traffic as we have l. c. l. railroad shipments.

So far, we have developed a rational method of estimating the probable through traffic which may be expected after a road has been improved by paving and traffic given time to develop. The next step is to discover what unit savings a road improvement will make.

Two-ton truck tests reported in the Iowa Service Bulletin indicate that such a truck will go nearly four times as fast and burn only half as much gasoline on a paved road as on an earth road. Speed increases and gasoline economies are less, proportionately, for macadam and gravel surfaces than for paving, but great enough to offer real savings.

Speed lessens certain costs per ton-mile, such as driver, insurance, obsolescence, interest, and garaging, all of which total about so much every day whether the truck runs fast or slowly. In Bulletin No. 393, the Bureau of Public Roads indicates that these per diem items total about 40 per cent of the total charges on an improved road.

There are certain other costs such as gasoline, oil, tires, repairs and general wear and tear which depend more directly on the power used per mile; these items may be expected to drop as the miles per gallon rise.

Truck hauling costs vary widely with price levels, the make of truck, its size, the efficiency of its use, and the roadway it goes over. A year's test by a truck manufacturer of two machines operated over pavement indicated average costs of about 5 cents per ton-mile. If, over an earth road, these machines traveled a little over a fourth as fast, the two-cent per ton-mile cost for time items would rise to seven cents; and if they used twice the gasoline per mile, the three-cent power charge would rise to six cents, making the total charge thirteen cents a ton-mile on an unimproved earth road against five on a pavement, a saving of eight cents per ton-mile on pavement. Macadam surface would cost about seven cents a ton-mile less than earth, gravel about five.

The cost of passenger car operation has been estimated to average eight cents a car-mile on pavement; being sufficiently powerful to make reasonable speed over almost any sort of surface, the passenger car saving will be more nearly proportional to power demands—gas consumption per mile. On such a basis, the savings due to a pavement may average about eight cents a mile, macadam six cents, and gravel three.

At a little over eight cents a ton-mile, 45 tons per year, the tonnage per unit of traffic factor, justify a maximum paved road charge of anything less than \$3.64 per mile. Similarly, at slightly less than eight cents a passenger car-mile, seventy passenger cars a year justify an expense of anything up to five dollars and a half a year. This limiting expenditure of \$9.14 per mile per traffic factor, if undiminished by any maintenance charges whatsoever, will carry about \$70 in ten-year, 5 per cent annuity bonds. Limits for macadam and gravel improvements, determined in the same way, approximate \$57 and \$34 per mile, respectively. Such is the evidence that:

Investments in road improvements for through or intercity traffic ought not to exceed, in northeastern Ohio, \$34 to \$70 a mile, multiplied by the product of the populations, in thousands, of the cities connected and divided by the distance between them in miles.

RURAL TRAFFIC

What is a highway improvement worth to the farmer?

Two solutions suggest themselves. One comprises a study of farm-to-market hauling costs under different conditions; the other the capitalization of both hauling and social returns in land values.

In 1917, in Hudson township, Summit County, with 60 per cent of the area seeded, an average of three-quarters of a ton of produce and supplies

were hauled for each gross acre of farm land; hauls averaged 2.38 miles, or $1\frac{3}{4}$ ton-miles per acre.

A team and driver at \$7 a ten-hour day might be expected to haul a ton on unimproved earth roads at 2 miles an hour loaded and to return at 3 miles an hour empty. A ton-mile haul then would cost a half plus a third of seventy cents, or fifty-eight cents. Hauling for the average acre would cost $1\frac{3}{4}$ times fifty-eight cents or just over a dollar an acre a year. Improved roads ought to save some of this dollar an acre a year.

Suppose, by saving an unusual part of the crop by quick hauling, or by permitting hauling at slack times of the year, or by allowing delivery when farm stuff prices are highest, the improvement saves the entire dollar. This dollar an acre a year will pay 5 per cent interest on and retire the principal of a loan of less than \$8 an acre in ten years. Therefore:

If hauling savings were all the benefit farmers in northeastern Ohio got from road improvement, less than \$8 an acre would be the limit they should be charged or that should be invested for their benefit.

There are other benefits: broadening opportunities to visit, to go to town, to church, to school. An idea of the farmer's valuation of the sum of these social values and the reduced hauling costs may be had by investigating farm land values along roads before and after they are improved.

Abutting the Akron-Copley pavement, built in 1917 and 1919, twenty-one tracts containing 583 acres increased in taxable values \$25 more an acre between 1915 and 1920 than did the average of the entire township. An investigation by the Federal Bureau of Public Roads, Bulletin 393, 1916, in eight counties scattered from New York to Mississippi, showed increases in farm land sales values of from \$5 to \$31 an acre on abutting farms after improvement.

Twenty-five dollars an acre seems, therefore, a reasonable estimate of the benefit of an improved road to the owner of average abutting farm property. In Summit County there are about 340 acres to each mile of road. Three hundred and forty times \$25 an acre gives an \$8,500 benefit to farm lands for each mile of improvement. This, then, is the evidence that:

Investments in road improvements for the benefit of rural traffic should be limited, in northeastern Ohio, to \$8,500 a mile.

INTERIOR OR TERMINAL TRAFFIC

Inside city limits, road traffic involves complications and densities which it is no part of this discussion to consider. Under one condition, however, provision for city traffic may require consideration by highway authorities, when allotments extend beyond city limits.

Such traffic, or prospective traffic in the case of projected allotments, is identical with interior traffic and might reasonably be expected to be provided for in the same way: by the construction of streets wholly or almost wholly paid for by special assessment on benefited property.

Suppose it is not. Assuming it is fair for the public to gamble on the success of a proposed allotment, it ought also to be fair to limit the public's contribution for highway improvement for such traffic to the maximum

possible return such a development might make to the public's road funds.

In Summit County, Ohio, the assessed valuation of real and personal property in the entire county, exclusive of Akron, averages \$550 an acre; Akron averages \$23,300 an acre. Development of average county property into average city property might be expected to raise tax valuations not more than \$22,750 an acre. County road taxes total thirty-one cents per \$1,000 in 1921; a \$22,750 increase in valuation per acre will return \$7.05 an acre to the county road funds; \$7.05 will pay 5 per cent interest on and retire a loan of \$54.50 in ten years. At \$50,000 a mile, which is less than some recent road paving contracts have been let for in this county, it would require 918 acres, or nearly $1\frac{1}{2}$ square miles, to be raised \$22,750 per acre each in order to pay the public for building one mile of paved highway. Fully developed, this area would have about 49 miles in its street system. Such is the evidence, then, that the financing of all or any material part of highway improvements for suburban traffic by general taxation serves only to increase tax burdens without compensating returns.

Most such traffic comprises light residential movements existing almost solely for the benefit of the immediate neighborhood. Financed entirely by special assessment, road improvements for suburban traffic may be distinctly worth while from a local benefit standpoint. It is interesting to note that, in the history of street paving, many cities which were almost entirely "in the mud" as long as the general city funds were required to carry the burden of paving, have been getting out quite rapidly after shifting the burden to abutting property owners.

SPECIFIC APPLICATIONS

We have applied these principles to an analysis of our highway system in Summit County. We have invested, or are planning to invest, four million dollars on highway improvements. Capitalized, the returns from this outlay total a little over eleven and a half million, leaving a reserve for maintenance and for service dividends of about seven and a half millions.

Unfortunately, there is a darker side. Half of this four millions has been spent on improvements worth only about nine hundred thousand dollars if they cost nothing for maintenance. An outlay of only two millions might have left us eight million and a half for maintenance and surplus, much more than doubling our return per dollar of outlay. And, most serious of all, every single one of our 1921 projects appears in the loss column, the excess of cost over returns for eleven hundred thousand dollars' outlay planned for 1921, totaling seven hundred thousand dollars.

CONCLUSION

Many of the figures used in this paper are approximations which future research, I hope, may make more exact. But the significance of great precision may be judged by the fact that doubling returns would shift only 17 per cent of the roads from unprofitable into the profitable class; and halving them throws only 12 per cent from the profitable into the unprofitable.

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